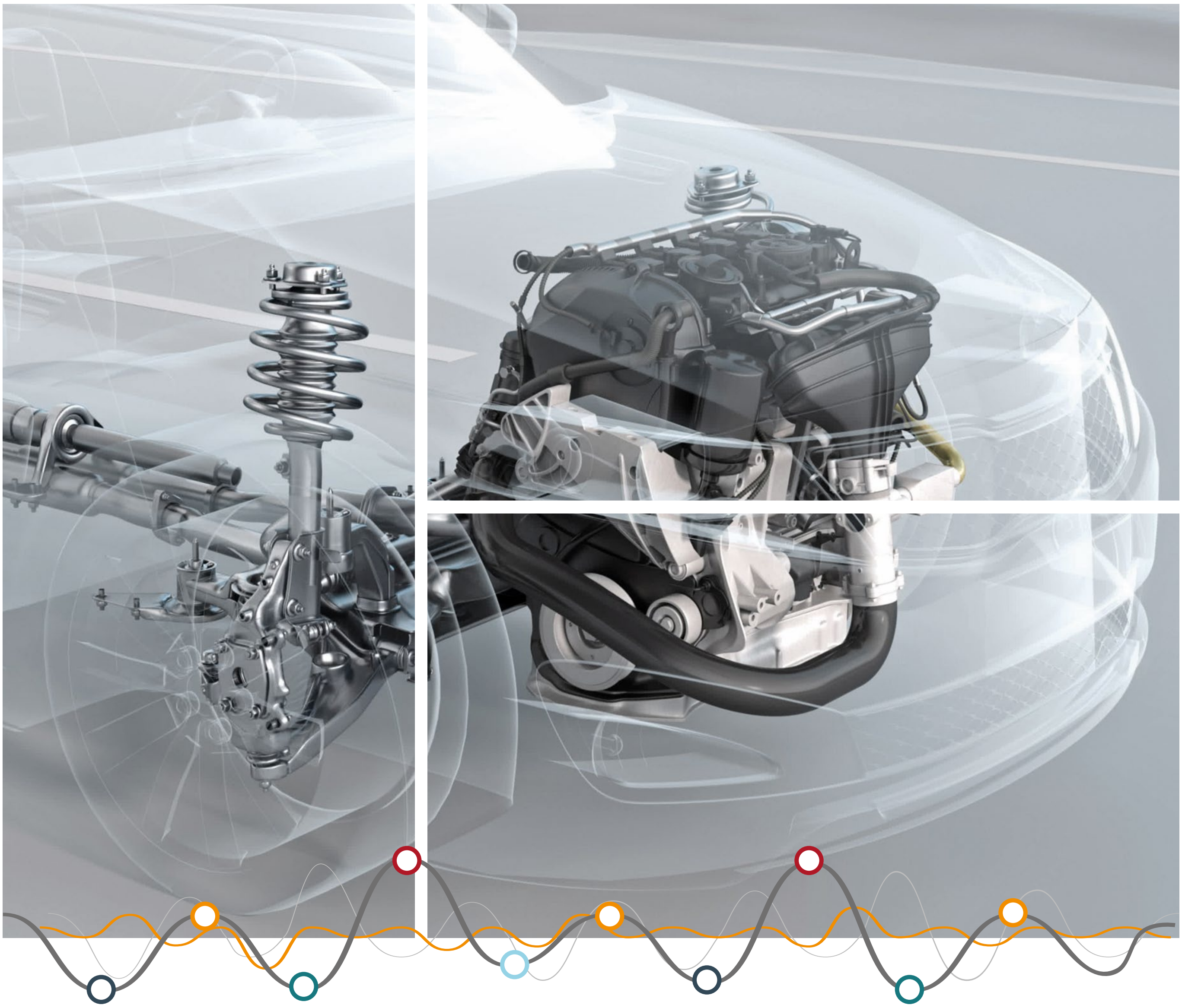
HPF 1.2 INTERCONNECTION SYSTEM

Meeting the Requirements of Extreme Vibration Applications

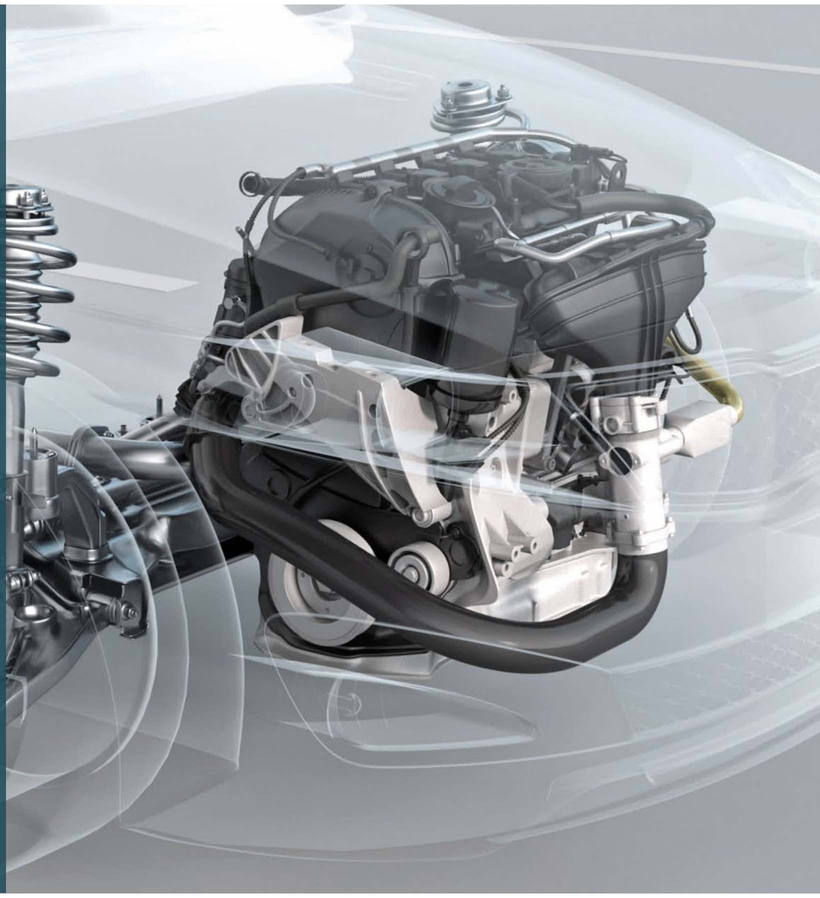


The evolution of modern high-performance combustion engines has created higher requirements for interconnection systems. Traditional electrical connector systems with a proven track record over many years must now withstand significantly increased vibration from the harsh environments of today's vehicles.

These requirements apply both to applications in high-performance engines with between eight and ten cylinders and also to lightweight low-displacement ultra-efficient engines. Therefore, car manufacturers' specifications for vibration loads as defined in test specifications for electrical connection systems are no longer sufficient. Currently, measured vibration loads can be greater by up to a factor of four.

TE Connectivity (TE) has addressed this challenge by developing the contact system HPF 1.2. When paired with a selection of purposely designed HPF connector housings, this system is capable of withstanding today's vehicles' increased vibration requirements. This white paper shares the innovations of the HPF 1.2 terminal system, its associated HPF Connector system, and its solution to solving high vibration requirements.

Content



Introduction

1.2 mm contact systems such as TE's MCON 1.2 connector series from two and up to twelve positions under the AK interface have become an established interface that is used for contacts to engine components, such as actuators, sensors and injection valves. Originally, this type of connector system was designed to support loads of 30 g Sinus and has provided highly reliable operations for many years. However, as today's cars continue to evolve, loads are exceeding actual connection values.

Engine tests executed in cooperation with the car manufacturers clearly indicated that the actual vibration profiles of the tested engines in operation exceeded the specified values by a wide margin. The tests indicated excitation levels of up to 80 g Sinus, over a widely distributed frequency range of between 200 Hz and 2000 Hz, depending on the engine type. This result means that the current spectrum of measured vibration load levels is higher than previously assumed by a factor of up to four, Fig. 1.

TE has developed an innovative terminal and connector system to meet new higher vibration requirements. It was evident that it would not be possible to manage a leap in the vibration load of this magnitude by optimizing an existing terminal or connector system.

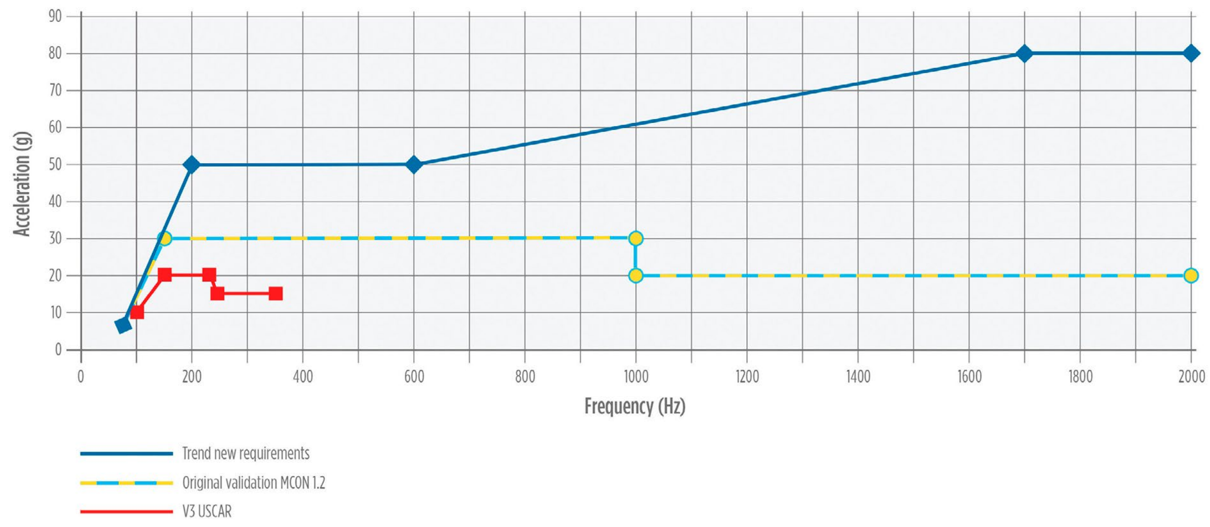


Fig. 1: Current vibration profile compared to previously applicable qualification requirements

The HPF 1.2 Interconnection System

HPF 1.2 is designed to be compatible with the MCON 1.2 connector system and is capable of withstanding high vibrations, as described in section one. A characteristic of HPF contact systems compared to other contact systems is the higher contact normal force, which is applied to the contact zone between the solid tab contact and the spring loaded receptacle contact.

The HPF 1.2 is an optimized design of the previous HPF 1.5 version and is designed for tabs with the dimensions of 1.2 mm x 0.6 mm. Given the abrasive damage in the contact points that occurs under high levels of vibration, the primary aim of the design was to avoid micro-movements in the contact zone between the tab and the HPF 1.2 system. To achieve this, the contact zone was mechanically decoupled from the remaining contact system. By so doing, micro-movements introduced by vibrational load were removed from the contact point of contact.

Structural Design

The core characteristic of the HPF 1.2 contact system is its special structure. The contact comprises two parts: the outer closed-box contact spring (shown in yellow in the illustration below) and the inner contact body (shown in light grey), Fig. 2.

The corrugated contact springs generate several contact zones positioned one behind the other to stabilize the position of the tab relative to the HPF 1.2. The crimp-type connection is designed for contacting cables with cross-sections ranging between 0.35 mm^2 and 1 mm^2. The HPF 1.2 with Ag (Silver) plating can be used for ambient temperatures of up to 150° C. Other surface finishes for higher temperatures are currently in the process of qualification.

The added meander-shaped geometry compensates micro-movements introduced in the axial direction through

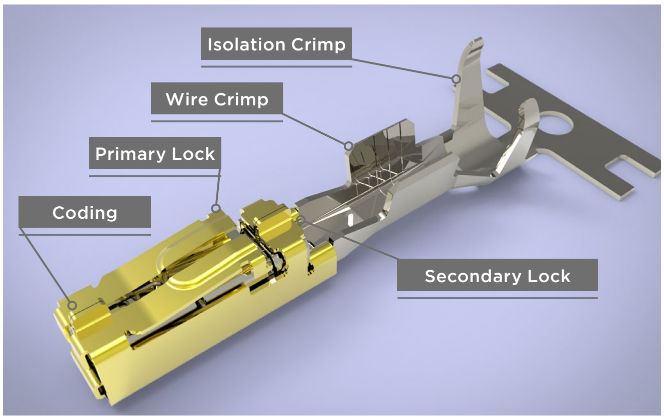


Fig. 2: Contact body and spring of the HPF 1.2

the cable ("concertina effect"). The external box spring provides low-friction guidance of the contact body and fixes the HPF 1.2 contact in the contact chamber of the connector housing.

This flexural stress fatigue in the contact body must be retained reliably in the elastic area of the copper material to safeguard desired mechanical endurance strength in the meander geometry. To achieve this the maximum admissible movement of the meander zone is limited by the design.

Connector Housing and Interface Compatibility
Given the high vibration loads of up to 80 g at 2000 Hz, this innovative contact design would not be sufficient on its own to fulfill technical application requirements. Thus, an optimized electrical connector concept designed as an overall system is also needed. To confirm that the HPF 1.2 connector system can be used with existing components, the system is designed to be interface-compatible with the VDA 1.2 as with the MCON 1.2 series.

Fig. 3 shows the structure of the features of the connector, terminal and seal of the HPF 1.2 interconnection system. The housing has been adapted to the contact in a number of ways in order to decouple the contact zone from the introduced movements realized in the HPF 1.2 to create an optimal effect. These effects include accuracy of fit in the contact cavity and a specific 20% longer special radial wire seal to prevent relative movements in the contact points. With its good damping properties, the housing material also contributes towards the overall performance of the connector system.

Test Results
Tests were performed at our Test Competence Center in Bensheim, Germany, using leading-edge capabilities for vibration testing to validate the connector components.

Overall, the vibration resistance of the HPF 1.2 connector system is four times higher than the most stringent vibration requirements specified today. Fig. 4 provides an example of one of the many successfully tested vibration profiles, carried out on the HPF 1.2. To assess contact quality, the contact resistance was measured during vibration testing. Fig. 5 indicates that stable electrical values were achieved during and after testing.

Another key assessment criterion is the evaluation of the contact surface after the end of testing. Fig. 6 shows minimal surface wear, with surfaces still having full functional integrity after the end of testing, Fig. 7.

Another finding noted is that for applications subject to the described vibration loads, suitable cables must be used (highly flexible fine stranded wires) to avoid cable breakages.

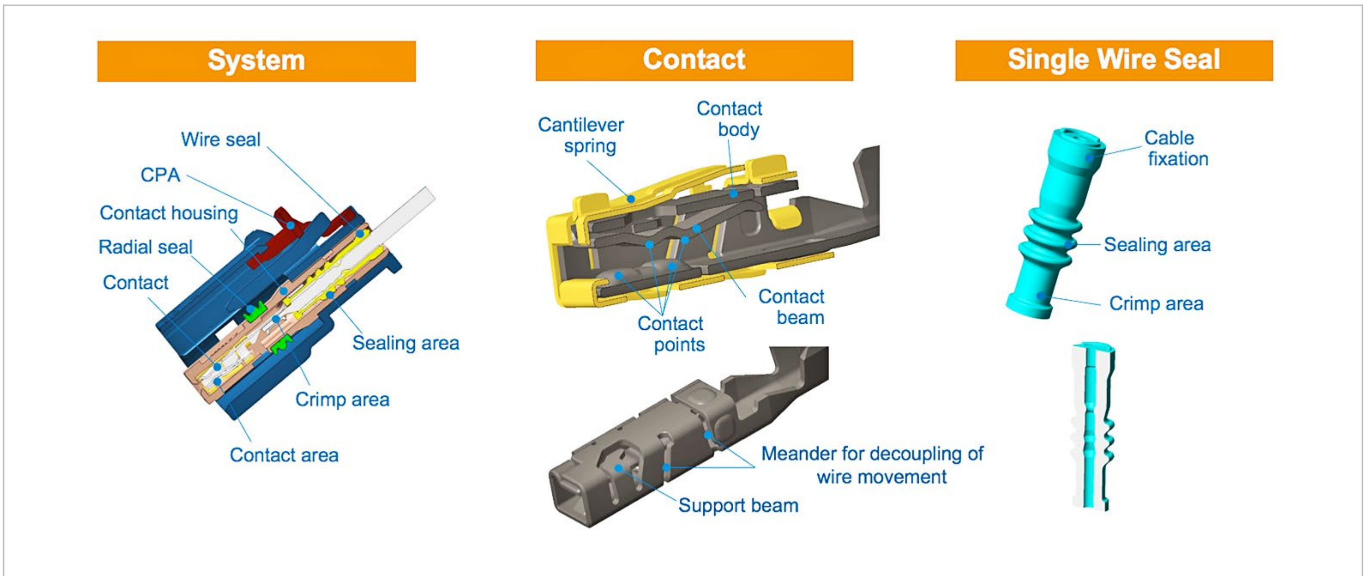
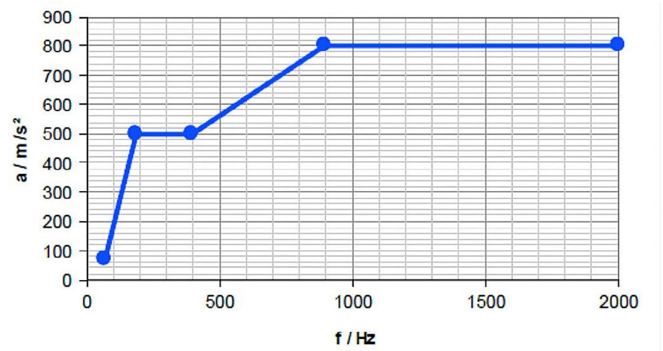


Fig. 3: The HPF 1.2 terminal, seal and its connector housing form a fully aligned system for high vibration applications.

Sinus 3 x 100h	
f / Hz	h / mm
70	0,7
f / Hz	a / m/s²
190	500
400	500
900	800
2000	800



Temperature Cycling	
t / min	T / ℃
0	20
60	-40
90	-40
240	140
420	140
480	20

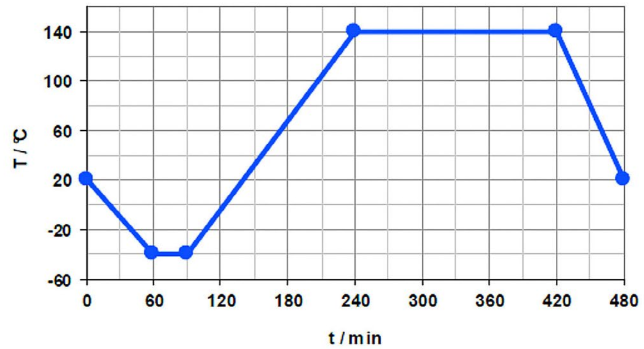


Fig. 4: Vibration profile with cyclical temperature changes successfully passed by the HPF 1.2 connector system

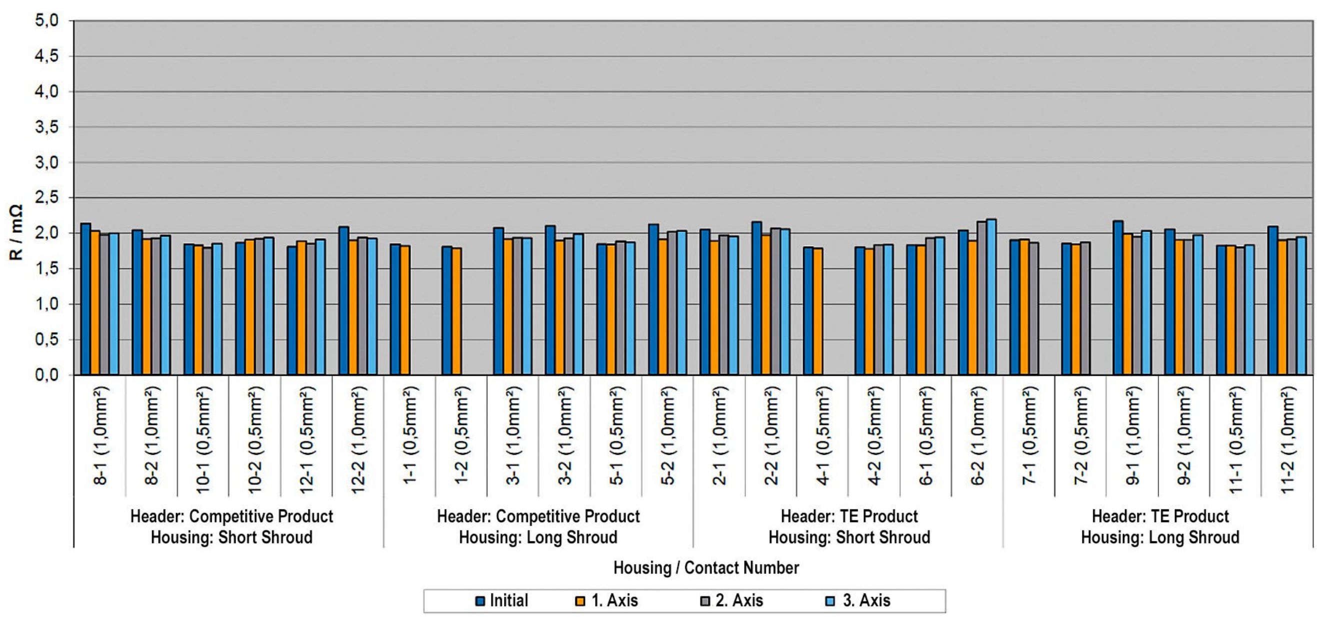
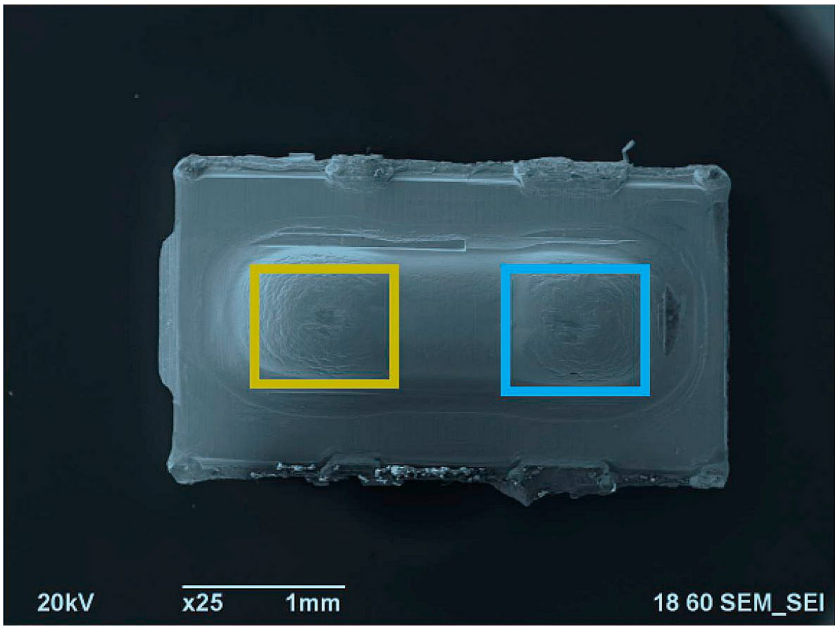


Fig. 5: Contact resistance before and after the test sequence defined in Fig. 4



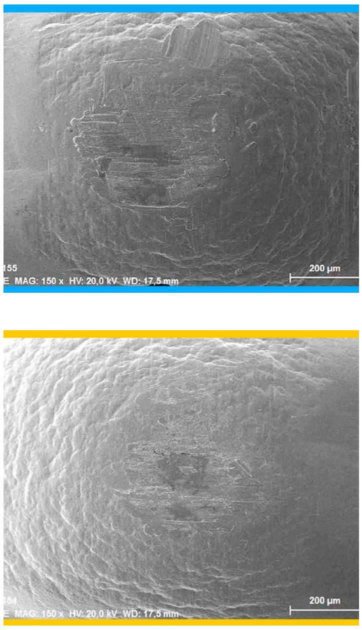


Fig. 6: Scanning electron microscope image to assess contact surfaces of tab and receptacle contact after the same test. No damage has occurred.

Fig. 7: Enlarged detail of the two contact points from Fig. 6

Conclusion

Within high-performance engines, it is primarily vibration-induced micro-movements at the contact zone that push today's connector systems to the limits of their performance. To meet this challenge, TE Connectivity has developed an innovative ultra-vibration resistant connectivity solution that decouples the micro-movements between the contact point and the cable.

This contact system has been designed using a software program that makes complex contact physics calculations that reliably indicate both the required mechanical and electrical parameters. The HPF 1.2 terminal is only one part of an overall system comprising the terminal, housing and cable fixture that has been optimized for extremely high vibration environments and can reliably operate under loads of up to 80 g Sinus at up to 2000 Hz.

About TE Connectivity

TE Connectivity is a $12 billion global industrial technology leader creating a safer, sustainable, productive and connected future. Our broad range of connectivity and sensor solutions, proven in the harshest environments, enable advancements in transportation, industrial applications, medical technology, energy, data communications and the home. With approximately 80,000 employees, including more than 7,500 engineers, working alongside customers in approximately 140 countries, TE ensures that EVERY CONNECTION COUNTS. Learn more at **www.te.com** and on **LinkedIn**, **Facebook**, **WeChat** and **Twitter**.

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